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Vienna, 13 April 2015

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Study of the Mediterranean desert dust outbreaks' vertical structure based on a synergistic use of satellite and ground retrievals

A. Gkikas[1], S. Basart[1], N. Hatzianastassiou[2], J. Pey[3], X. Querol[4], V.Amiridis[5], O. Jorba[1], S Gassó[6], J. M. Baldasano[1,6]

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Introduction

- Mediterranean is affected by dust outbreaks throughout the year
- Their spatial and temporal characteristics (Moulin et al., 1998, Gkikas et al., 2013) apart from the dust sources are mainly determined by the prevailing atmospheric circulation (Gkikas et al., 2014)
- Dust transport over the Mediterranean has a multilayered structure (Hamonou et al., 1999) in contrast to the Atlantic Ocean (SAL, Karyampudi et al., 1999)
- Description of the Mediterranean dust outbreaks based on lidar measurements (Papayanis et al., 2008) and therefore geographically limited
- European Aerosol Research Lidar Network (EARLINET, Bösenberg et al., 2003)
- Limited/Few studies based on satellite retrievals (Amiridis et al., 2009) and modelling techniques (Alpert et al., 2004)
- Interaction with the radiation → atmospheric dynamics (Mallet et al., 2009)
- Consideration of radiative impacts in numerical simulations improve weather models' forecasting accuracy (Pérez et al., 2006)

Satellite and ground datasets

- **Gridded daily satellite retrievals provided at 1ºx1º spatial resolution**
- **MODIS – Terra (2000 – 2013) & MODIS – Aqua (2003 – 2012) – C051, L3**
  - Aerosol Optical Depth at 550nm (AOD550nm)
  - Ångström exponent (land ➔ 470 – 660nm, sea ➔ 550-865nm)
  - Fine Fraction
  - Effective radius (over sea)

- **Earth Probe TOMS (2000 – 2004)**
  - Aerosol Index (AI)

- **OMI-Aura (2005 – 2013)**
  - Aerosol Index (AI)

Columnar data

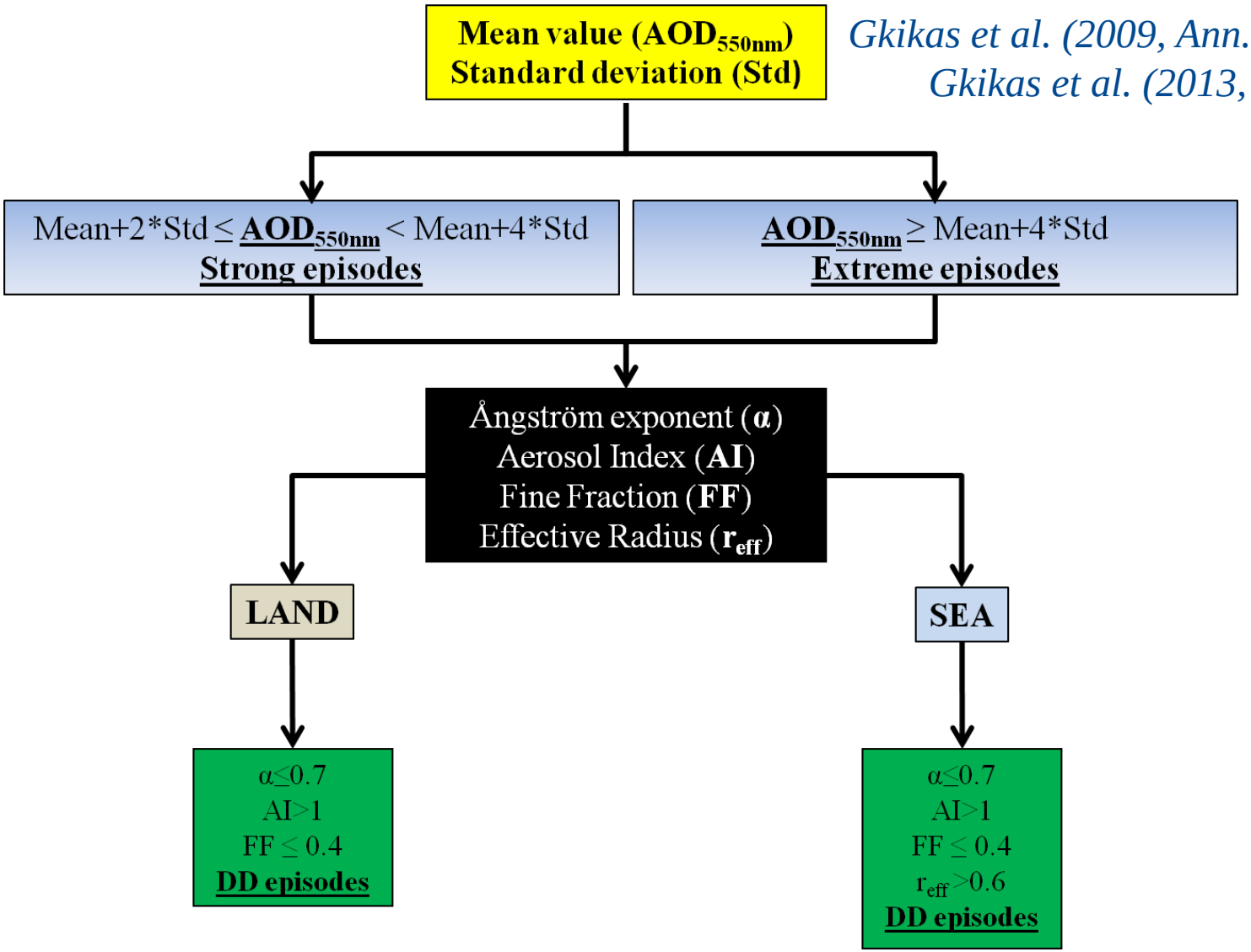
- **CALIOP - CALIPSO (2006 – 2013) – Versions 3.01 & 3.02**
  - Vertical Feature Mask (Level 2, 5km spatial resolution)
  - APro files (Level 2, 5km spatial resolution)
    - ✓ CAD score
    - ✓ Total backscatter coefficient at 532nm (β_{532})

Vertical data

- **Daily AERONET Level 2.0 optical properties over the period 2000 – 2013**
- **Daily PM_{10} measurements (2001 – 2011) – [18 RB & 4 SUB stations]**

Identification of desert dust (DD) episodes

Gkikas et al. (2009, Ann. Geophys.)
Gkikas et al. (2013, ACP)



Implementation of the algorithm in each grid cell

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THE REGIME OF MEDITERRANEAN DESERT DUST OUTBREAKS

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Frequency of occurrence of dust outbreaks (episodes/year)

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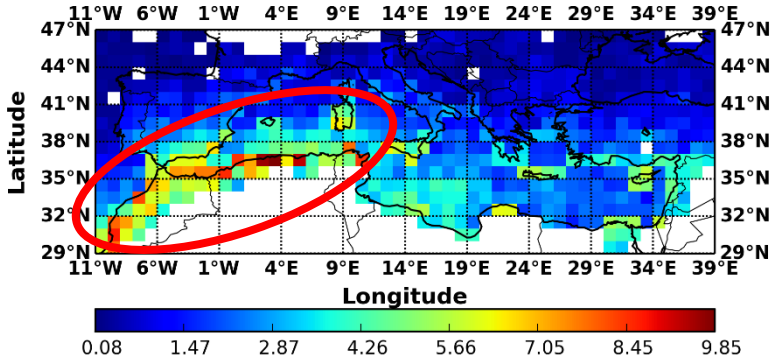
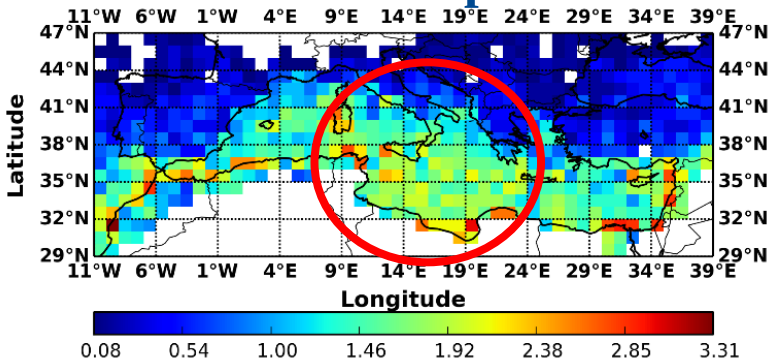
Strong DD episodes

Extreme DD episodes

2000 – 2013 MODIS-Terra

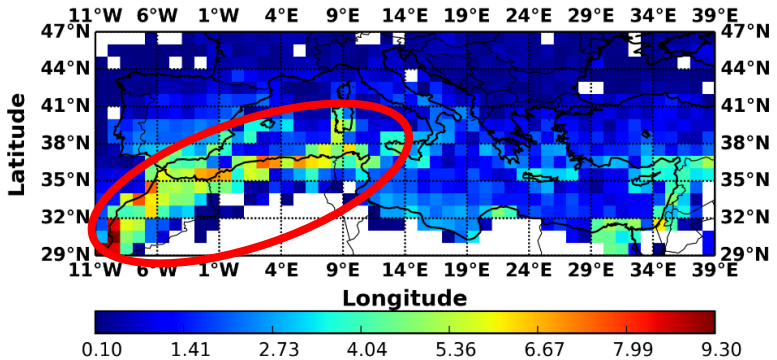


9.9

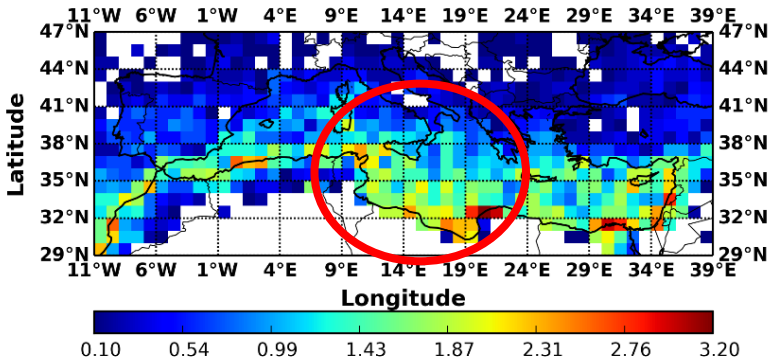


3.3

2003 – 2012 MODIS-Aqua

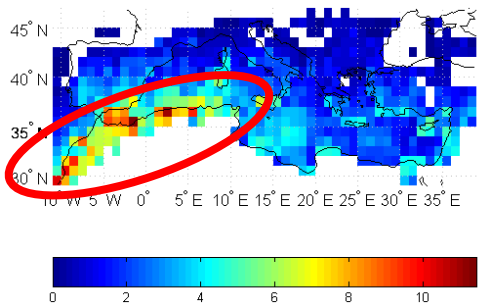


9.3

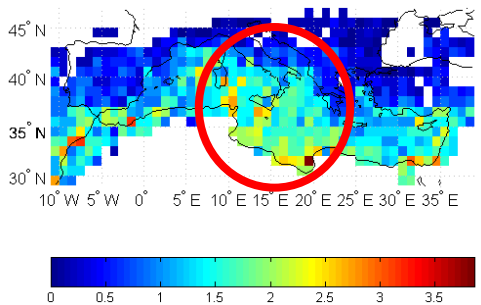


3.2

2000 – 2007 MODIS-Terra *Gkikas et al. (2013, ACP)*



11.4



3.9

- Similar spatial patterns among the different study periods
- MODIS-Terra: Reduction of the frequencies

Intensity of dust outbreaks (AOD_{550nm})

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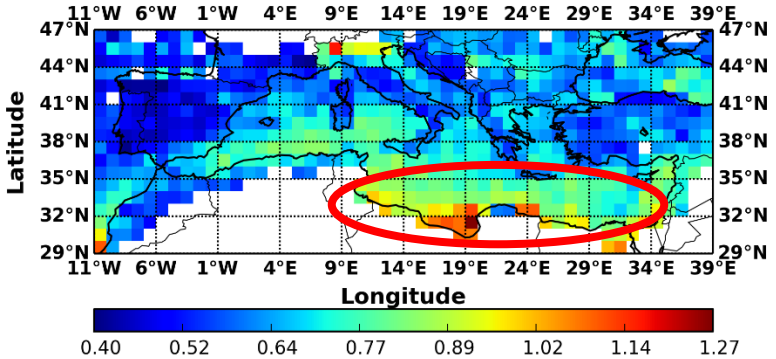
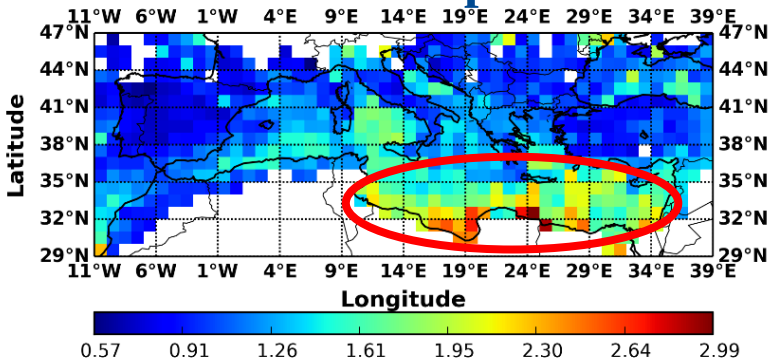
Strong DD episodes

Extreme DD episodes

2000 – 2013

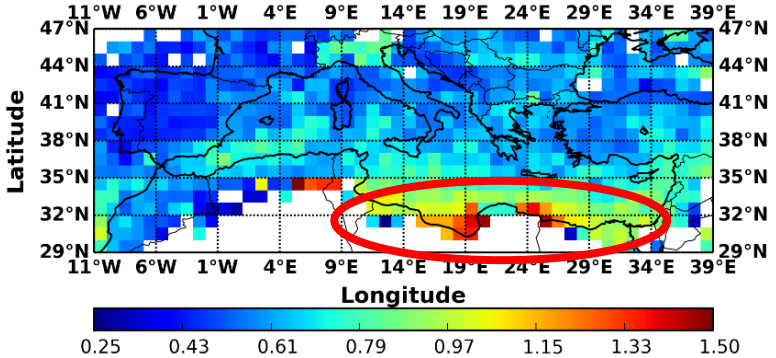


1.3

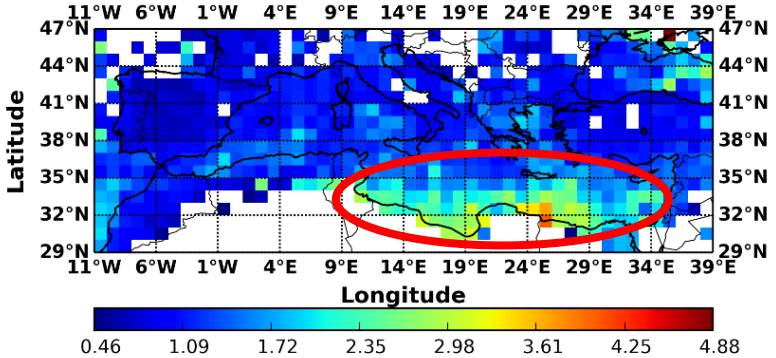


3.0

2003 – 2012



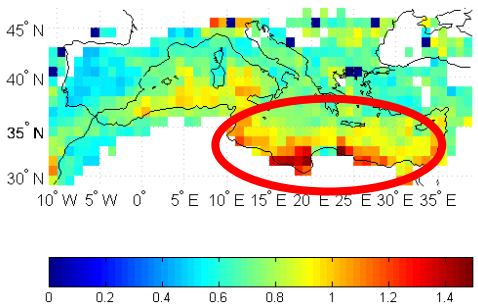
1.5



4.0

2000 – 2007

Gkikas et al. (2013, ACP)



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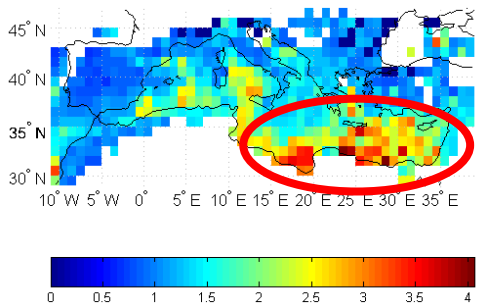

4.1

- Similar spatial patterns among the different study periods
- MODIS-Terra: Reduction of the intensities

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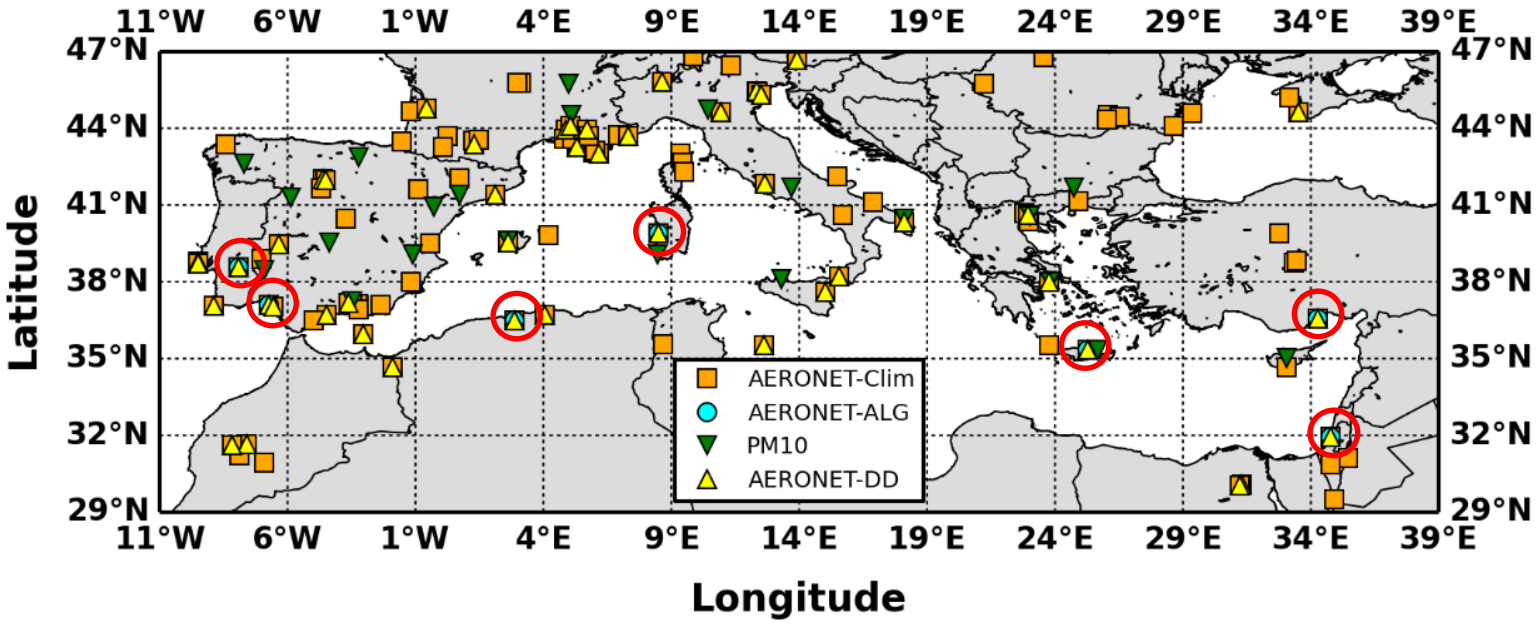
EVALUATION OF THE SATELLITE ALGORITHM AGAINST SURFACE MEASUREMENTS

European Geosciences Union
General Assembly 2015
Vienna | Austria | 12 – 17 April 2015

AERONET and PM_{10} sites

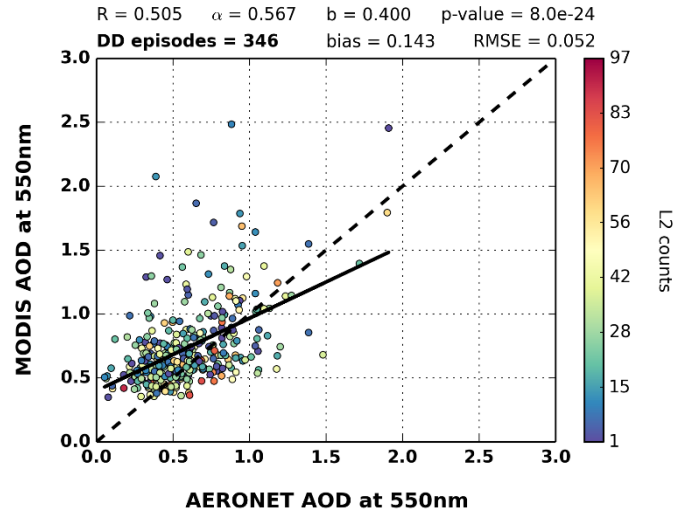


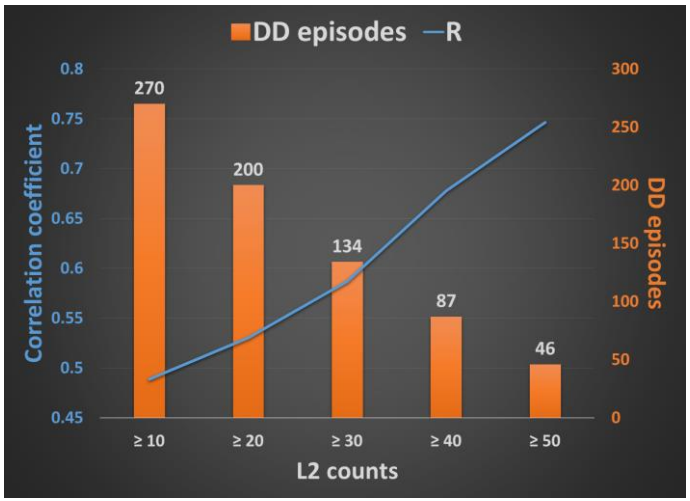
109 Stations
46 Stations
7 Stations
22 Stations

Station	Study period
Blida	7/11/2003 – 18/2/2012
El Arenosillo	1/3/2000 – 21/2/2010
Evora	4/7/2003 – 28/2/2013
FORTH CRETE	23/1/2003 – 6/8/2011
IMC Oristano	30/5/2000 – 28/2/2003
IMS METU ERDEMLI	1/3/2000 – 28/2/2013
Nes Ziona	1/2/2000 – 28/2/2013

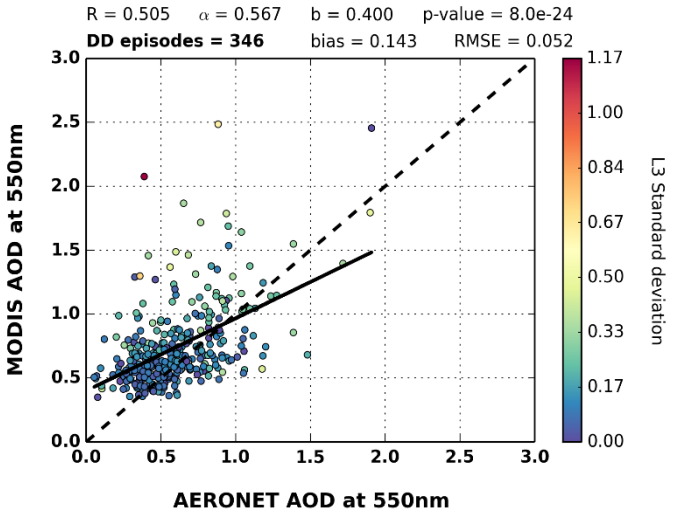
Scatterplot of AERONET and MODIS-Terra AODs

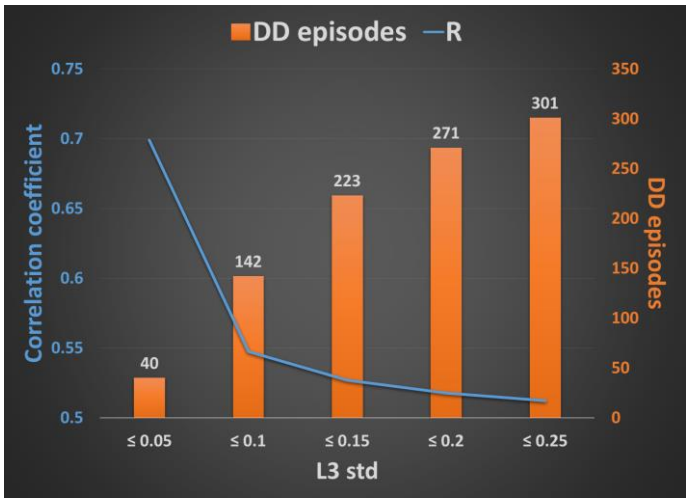
Resolved by Level 2 counts





Resolved by Level 3 std

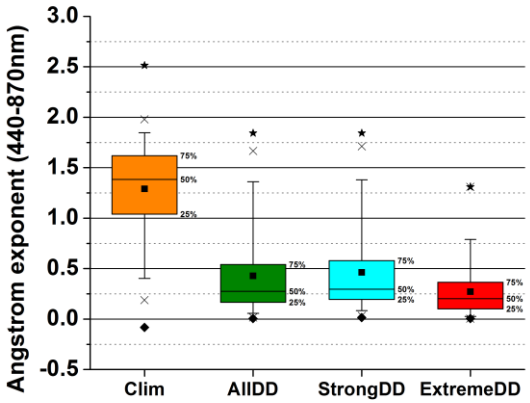




Better agreement between ground and satellite AODs for L3 retrievals with higher sub-grid spatial representativeness and homogeneity

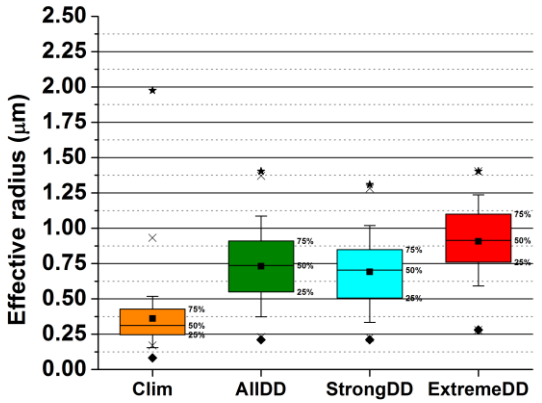
AERONET – Optical properties
MODIS-Terra (2000 – 2013)

Ångström exponent



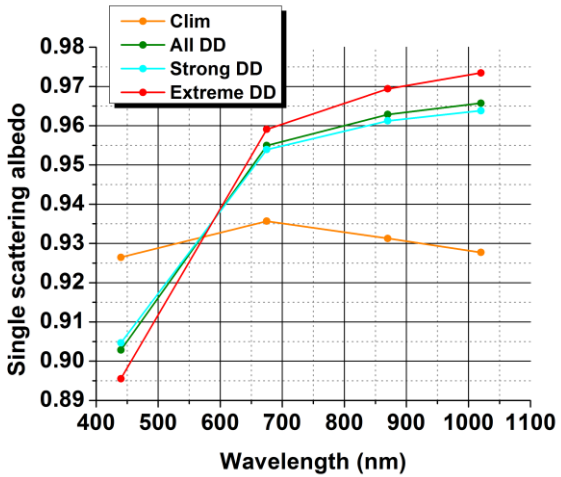
$\alpha_{440\text{-}870nm}$

Effective radius

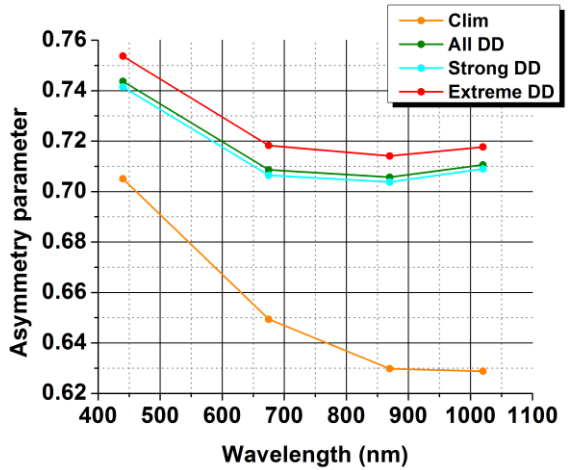


r_{eff}

Single scattering albedo



Asymmetry parameter



Typical spectral variation, indicative of dust aerosols, for ω and g values

Intercomparison of ground and satellite algorithms

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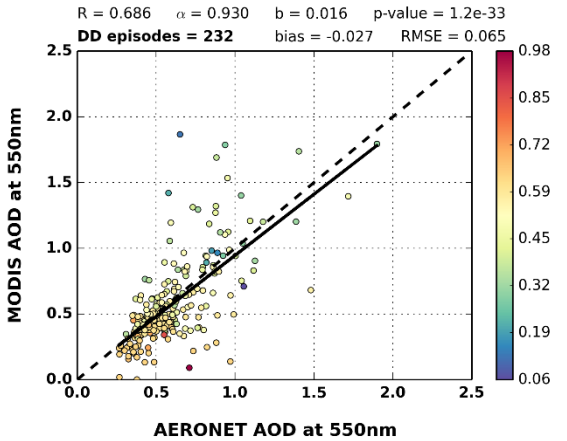
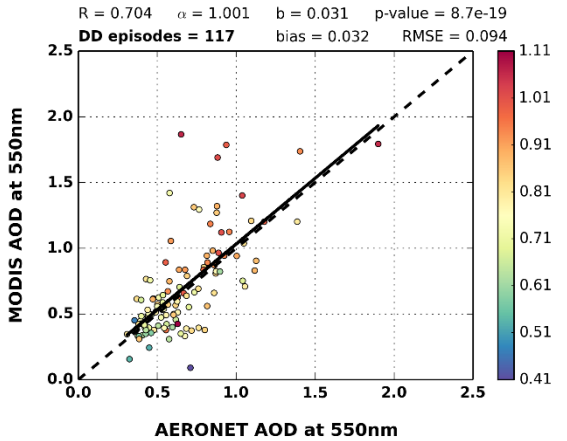
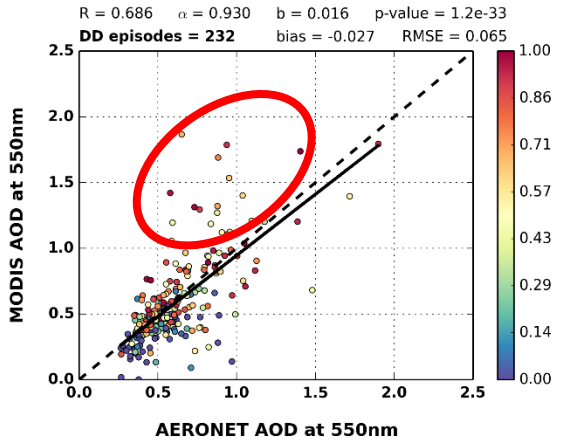
Identification of DD episodes based on AOT_{870}, $\alpha_{440-870}$ and r_{eff} AERONET retrievals

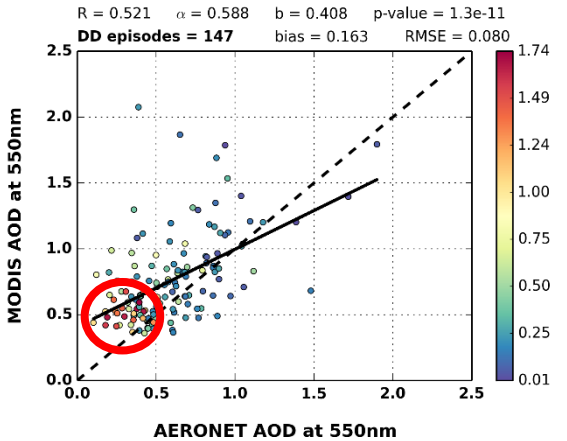
AERONET

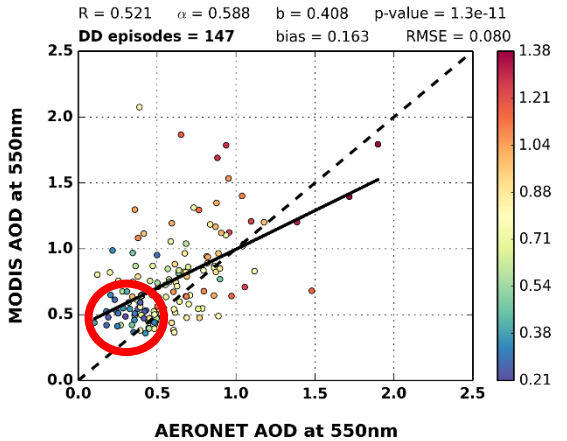


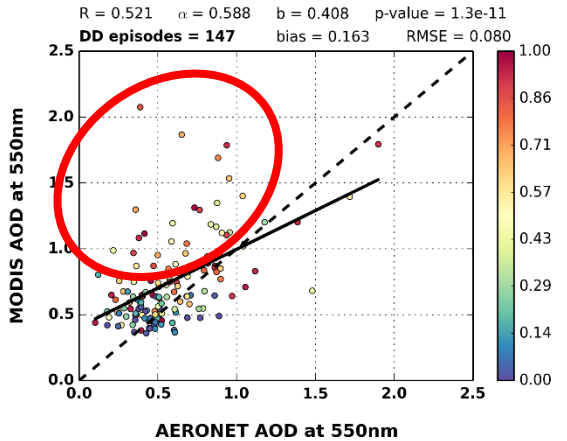




MODIS-Terra



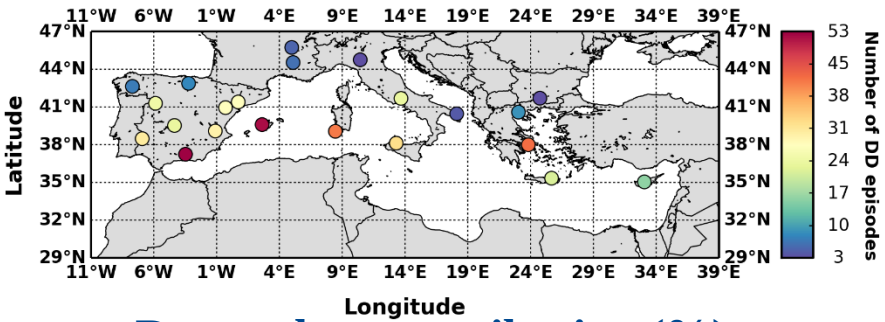




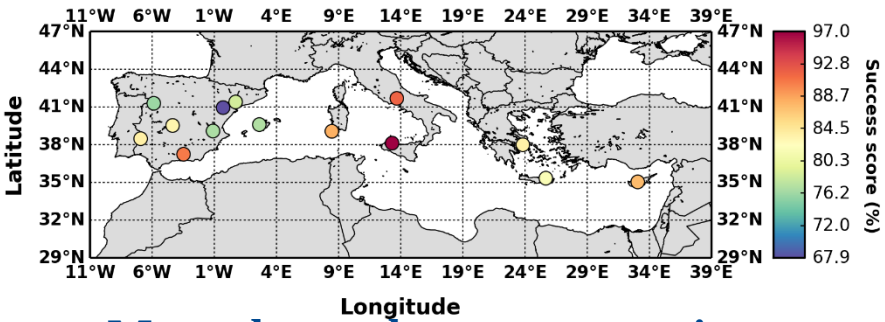
- Better agreement between AERONET and MODIS when ground retrievals are used
- About 15% of the pixel level DD episodes is misclassified by the satellite algorithm
- Cloud contamination can cause overestimation of the DD episodes' intensity

Comparison against PM_{10} measurements

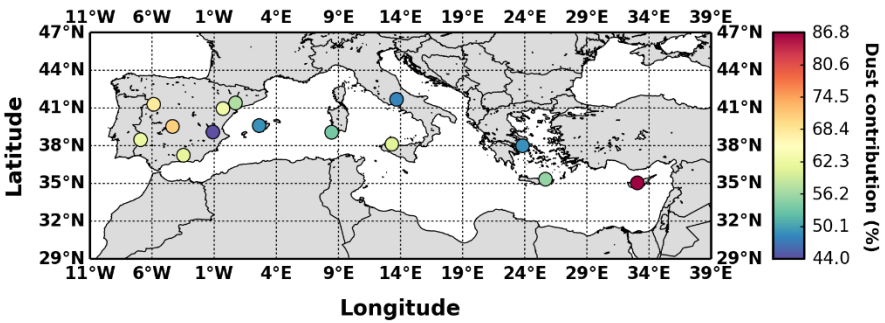
Number of DD episodes



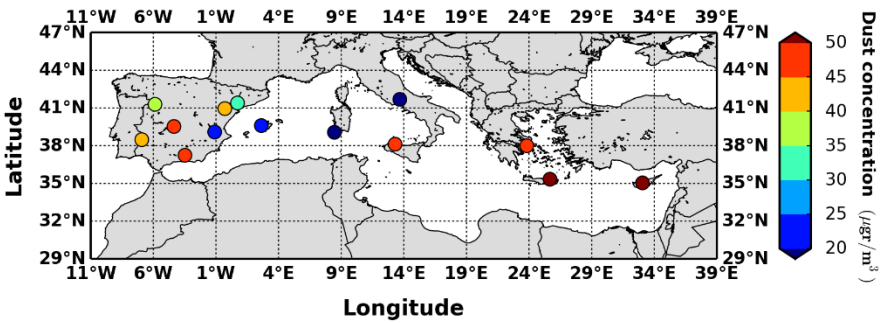
Success score



Desert dust contribution (%)



Mean desert dust concentration



- Total and dust PM_{10} concentrations (Pey et al., 2013)
- Number of DD episodes: 3 – 53
- In 14 out of 22 stations more than 10 DD episodes have been identified
- **Success score:** 67.9% - 97%
- **Desert dust contribution:** 44% - 86.8%
- **Mean desert dust concentration:** 20 μgr/m^3 – 50 μgr/m^3
  - **Min:** 17 μgr/m^3 (Censt, Sardinia)
  - **Max:** 223 μgr/m^3 (Ayia Marina, Cyprus)

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3D STRUCTURE OF THE MEDITERRANEAN DESERT DUST OUTBREAKS

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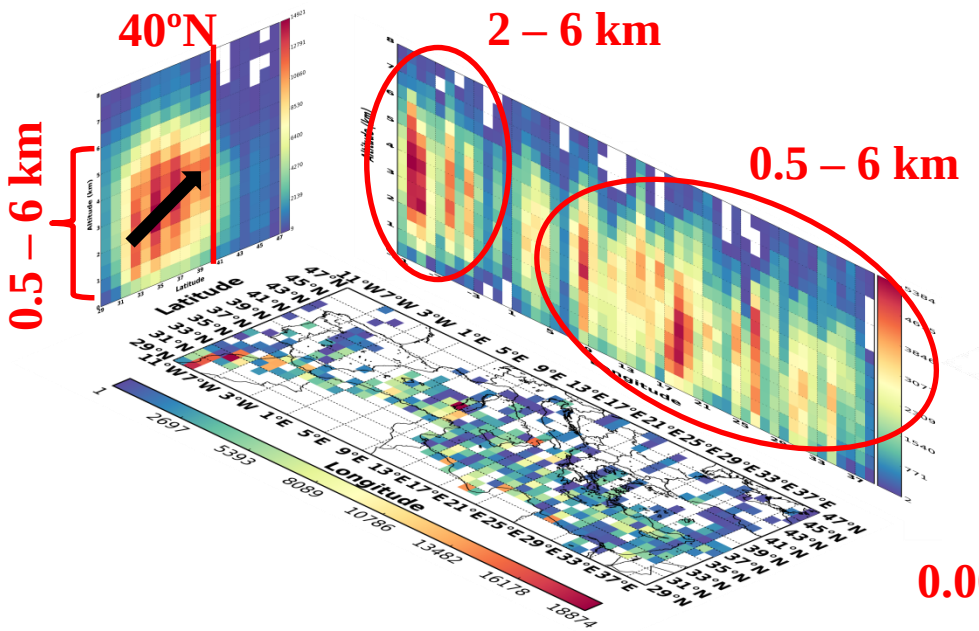
Vertical structure of desert dust outbreaks over the Mediterranean

- 16 layers up to 8km
- Boxes of 1ºx1º spatial resolution (surface area) and 500m height
- CALIPSO VFM: Dust & Polluted dust
- -100 ≤ CAD ≤ -20 (Winker et al., 2013)

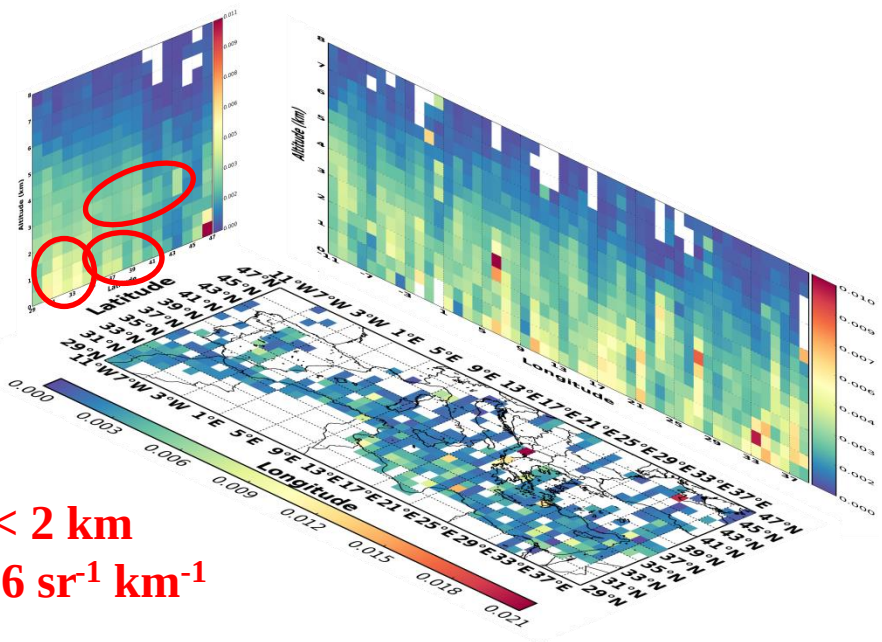
CALIPSO dust observations



Increasing height with latitude

Decreasing base height with longitude

Total backscatter coefficient (532nm)



< 2 km

0.006 sr^{-1} km^{-1}

< 1.5 km (35ºN - 38ºN)

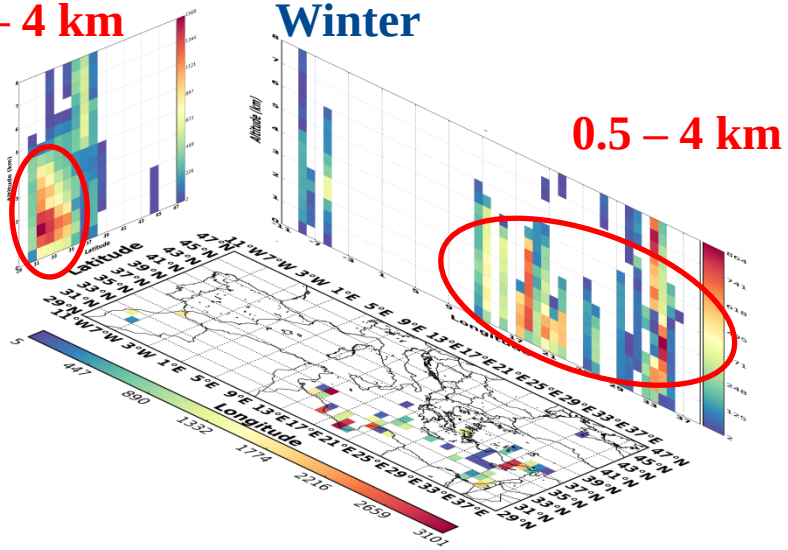
2 – 4 km (35ºN - 43ºN)

Seasonal variation of dust outbreaks' vertical structure (dust observations)

0.5 – 4 km

Winter

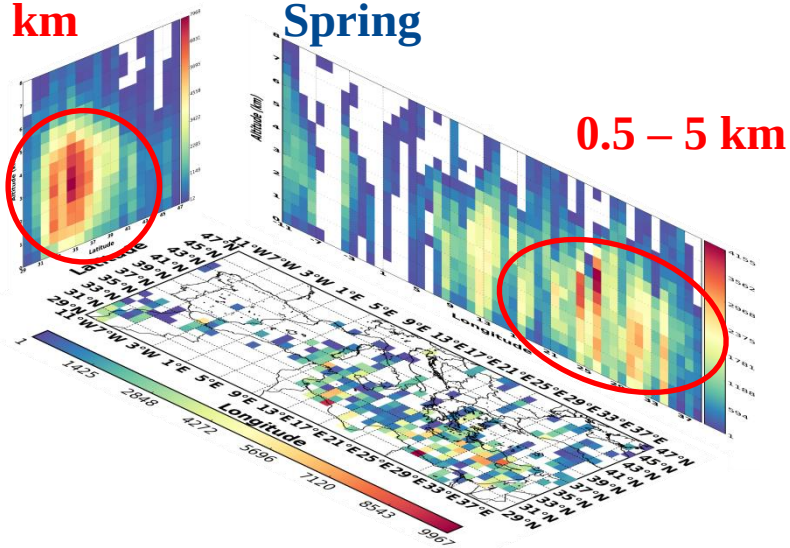
0.5 – 4 km



0.5 – 5.5 km

Spring

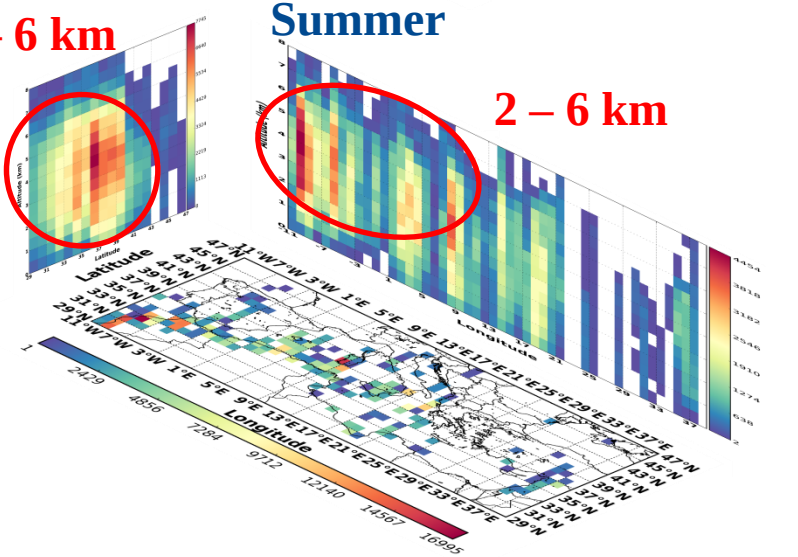
0.5 – 5 km



1 – 6 km

Summer

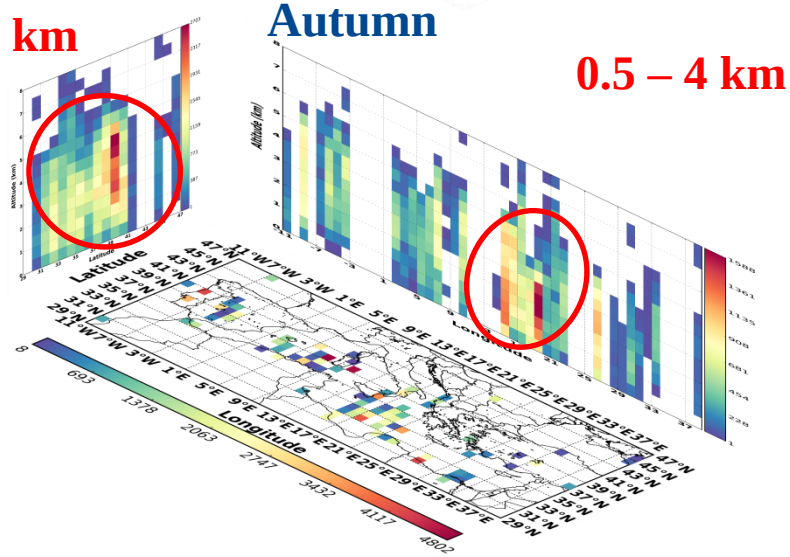
2 – 6 km



1.5 – 4.5 km

Autumn

0.5 – 4 km



Seasonal variation of dust outbreaks' vertical structure (β_{532})

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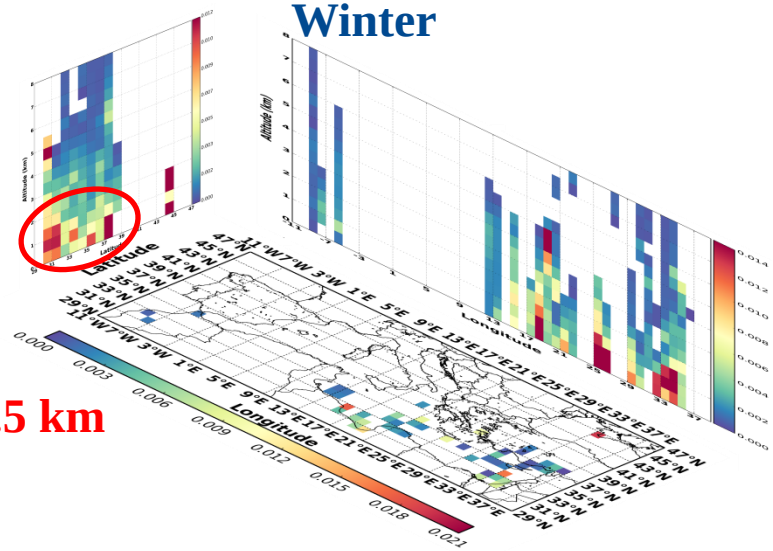
Winter

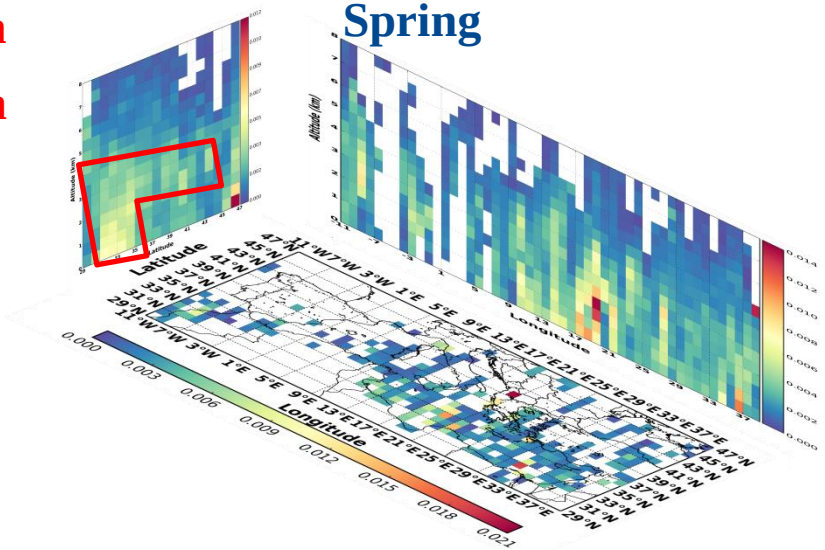
< 1.5 km

< 4 km

2-4 km



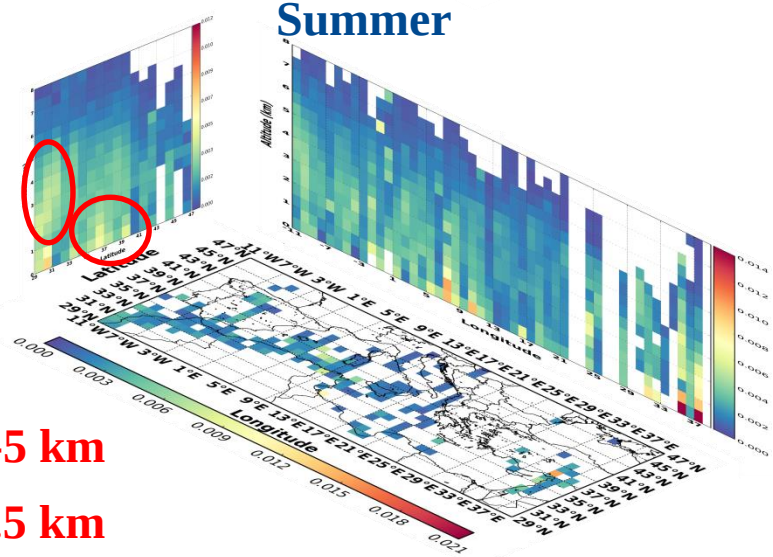
Spring



Summer

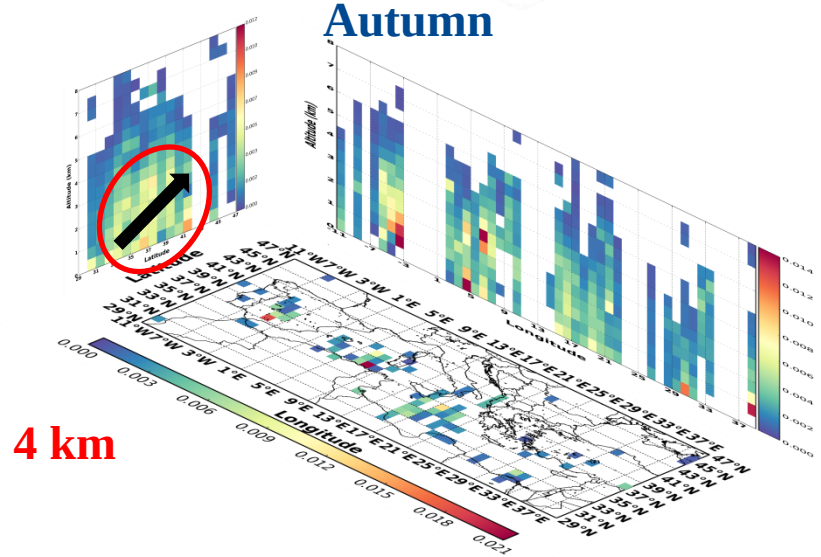
1.5-5 km

< 2.5 km



Autumn

< 4 km



Conclusions – Perspectives

- Frequency: Strong (10 episodes/year, W. Mediterranean), Extreme (3.3 episodes/year, C. Mediterranean)
- More intense (up to 4.0) DD episodes over the eastern parts of the Mediterranean Sea
- Good performance of the satellite algorithm based on the evaluation of its outputs against AERONET retrievals and PM_{10} concentrations
- The transported dust particles over the Mediterranean are mainly detected between 0.5 and 6 km (spring, summer)
- W. Mediterranean (2-6 km), C. & E. Mediterranean (0.5-6 km)
- Maximum β_{532} values below 2 km and near to the dust sources
- High β_{532} values: < 2 km (35ºN - 38ºN) and 2 – 4 km (35ºN - 43ºN)
- Dust layers with high β_{532} values over the Mediterranean in spring

Selection of 27 desert dust outbreaks in order to estimate their impact on radiation budget and atmospheric dynamics based on NMMB/BSC-Dust model

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EXCELENCIA SEVERO OCHOA

Study of the Mediterranean desert dust outbreaks' vertical structure based on a synergistic use of satellite and ground retrievals

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